5G NR Test & Measurement challenges and how to address them

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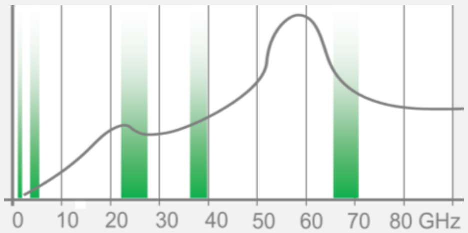
Agenda

- 5G introduction
- 5G gNodeBs - Critical quality factors and how to measure them
- Temperature testing on FR2 devices
- Comparison of different compact ranges

5G Key Technology Components

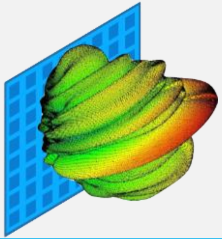
NR builds on four main pillars

New Spectrum



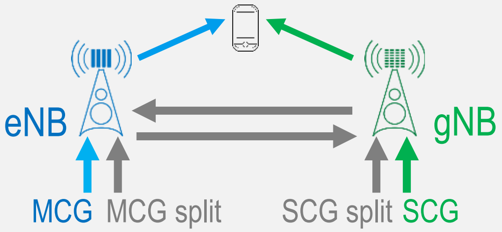
- < 1GHz
- ~ 3.5 GHz
- ~ 26/28/39 GHz

Massive MIMO & Beamforming



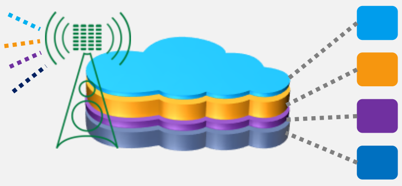
- Hybrid beamforming
- > 6GHz also UE is expected to apply beam steering

Multi-Connectivity



Initially based on Dual Connectivity with E-UTRA as master

Network flexibility - virtualization

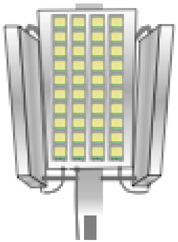


- Flexible physical layer numerology
- Network Slicing
- NFV/SDN

5G NR FR1 gNodeBs

Critical quality factors and how to measure them

Critical quality factors for multi-array (gNodeB) antennas



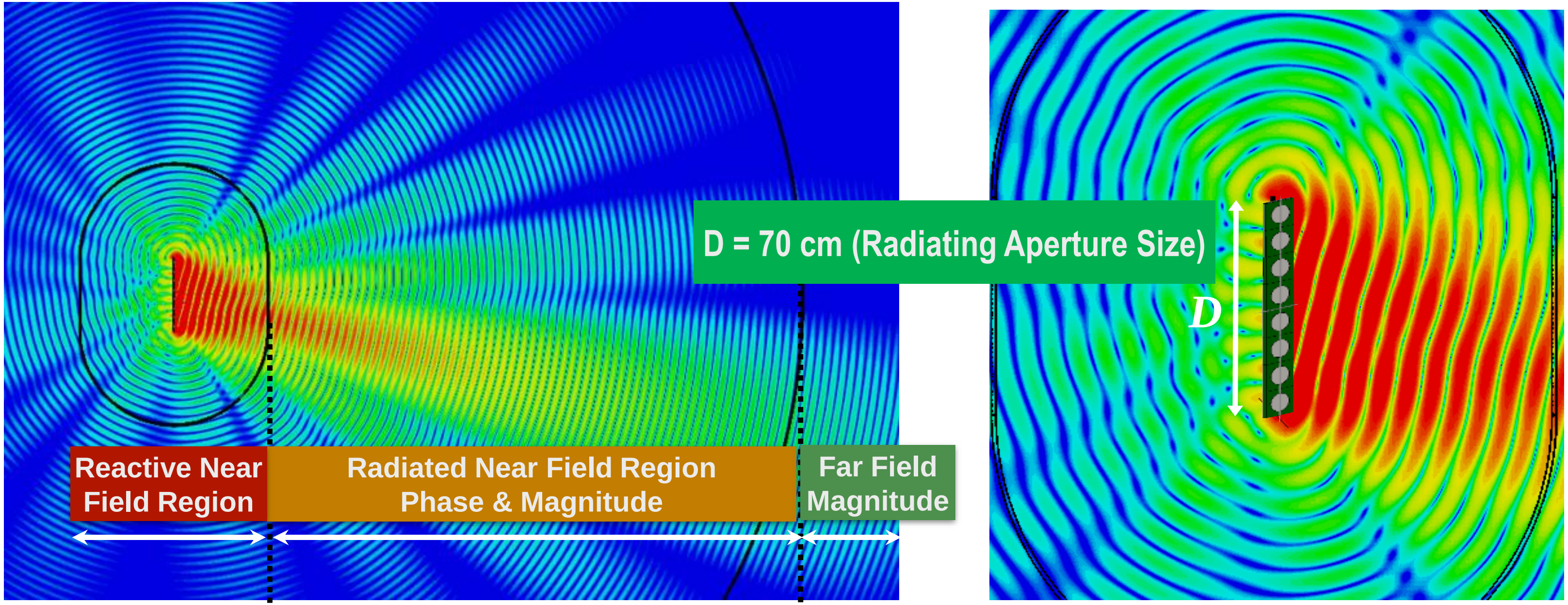
- Finding broken antennas / patches
- Phase / amplitude alignment between antenna elements / calibration
- Mutual coupling between elements
- Cross-polarization isolation
- EIRP / EIS patterns
- Maximum output power - intermodulation
- EVM, ACLR

OTA Tests are essential

OTA measurements should be done in far field…

Basestation Antenna Array at 3.5 GHz

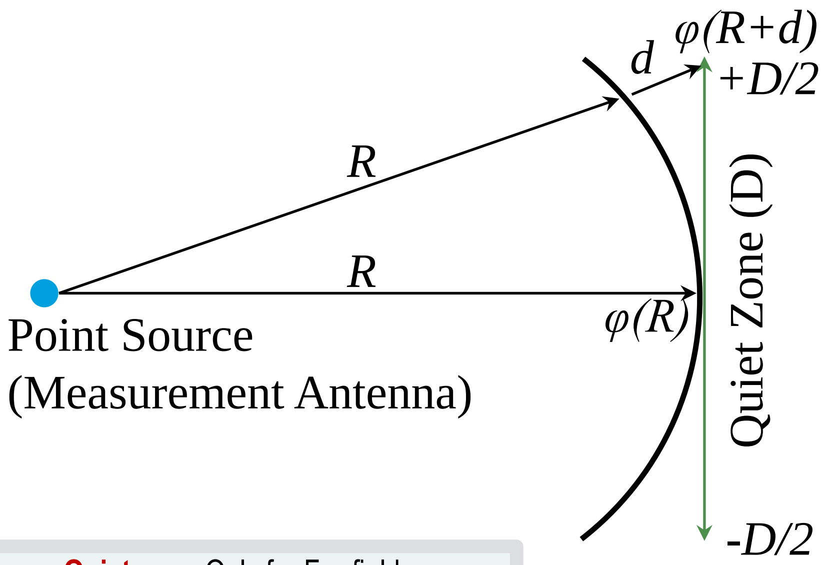
Reactive Near Field Region



$$0.62\sqrt{\frac{D^3}{\lambda}} = 1.2\ m$$

$$\frac{2D^2}{\lambda} = 12\ m$$

What is the Quietzone (in Farfield)?



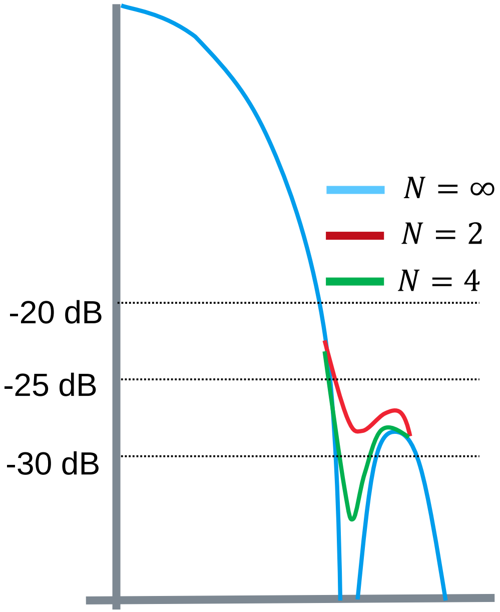
Quietzone: Only for Far-field measurements

Near-field does not have a "quiet zone"

Quiet Zone Phase Deviation vs. Measurement Error

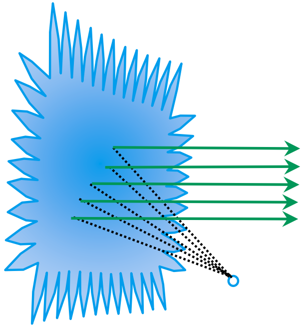
$$R_{min} = \frac{\pi D^2}{4\lambda\Delta\varphi_{max}} = \frac{ND^2}{\lambda}$$

$R_{min}(N)$	Phase Deviation
D^2/λ	45 degrees
$2D^2/\lambda$	22.5 degrees
$4D^2/\lambda$	11.2 degrees
$8D^2/\lambda$	5.6 degrees

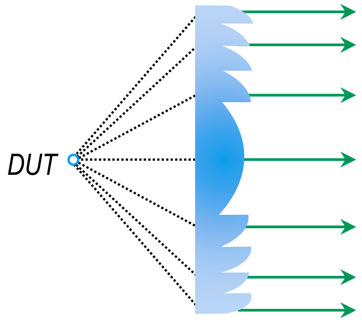


High Gain Antenna Pattern

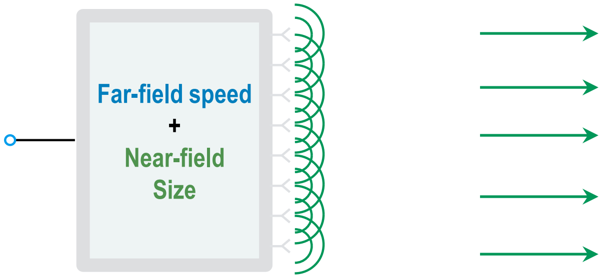
Far-field in Near-field Systems: Plane-Wave Synthesis



Reflector: Compact Antenna Test Range

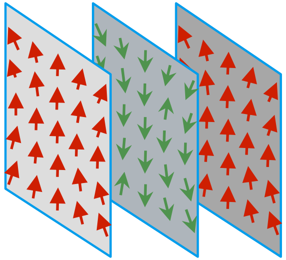


Fresnel Lens (Fourier Optics)



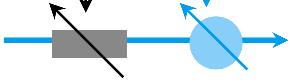
Near Field Plane Wave Synthesis

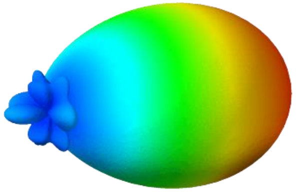
Complex near-field wave generated



$$f_{x,y} = A \iint E_{x,y} e^{+j\mathbf{k}\cdot\mathbf{r}} \, dx \, dy$$

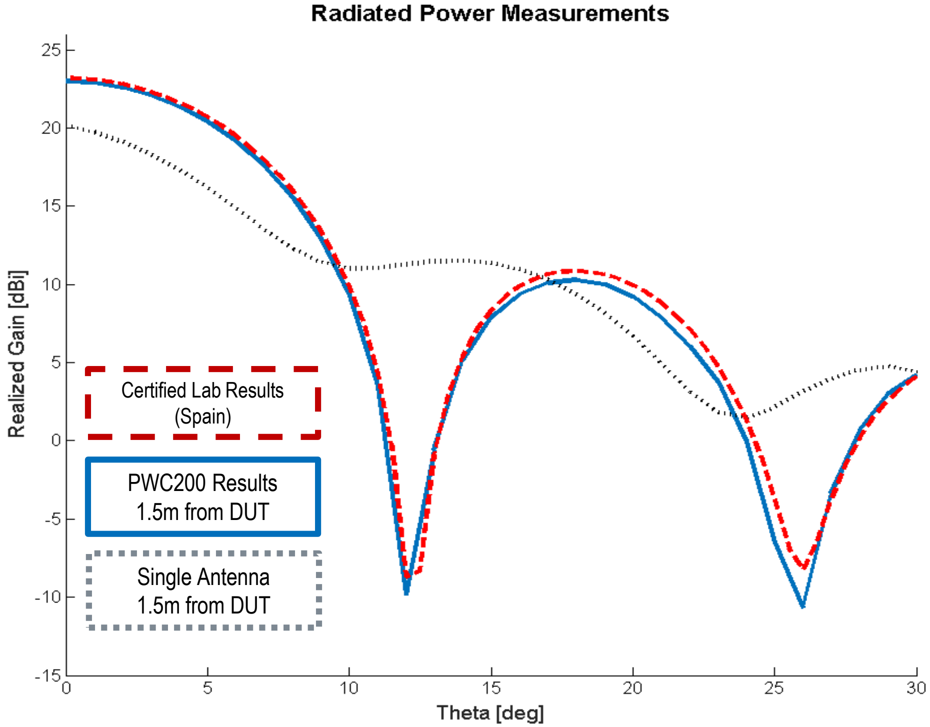
Amplitude Phase

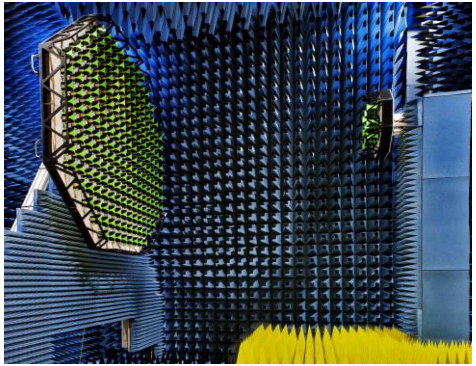




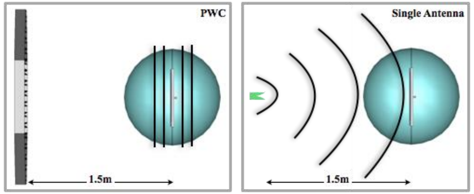
Plane wave far-field received

Verification of PWC200 Concept (EuCAP2018 paper)





1. Calibration with PWC-CAA1
- PWC200 Array
- Path loss
  (Single Vivaldi, PWC200)



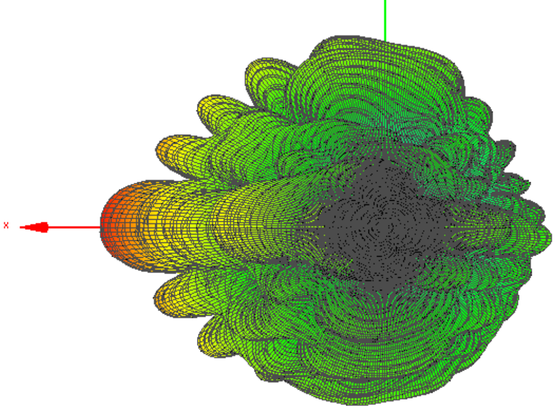
2. DUT measurement with
- Single Vivaldi
- PWC200

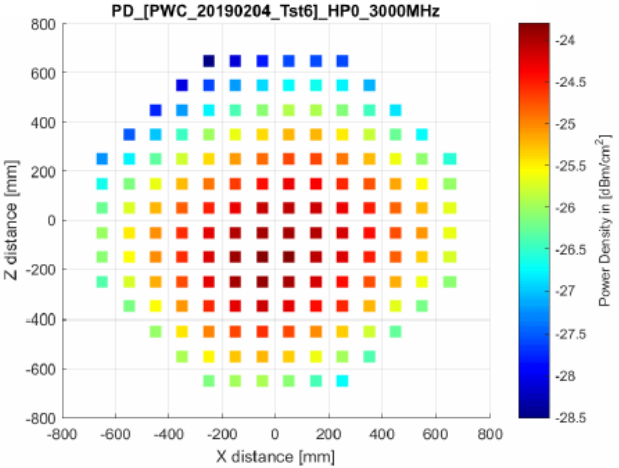
PWC200 Measurements

1. RF-fed AUT (passive)
   radiation pattern, gain, efficiency, crosspolarization, …

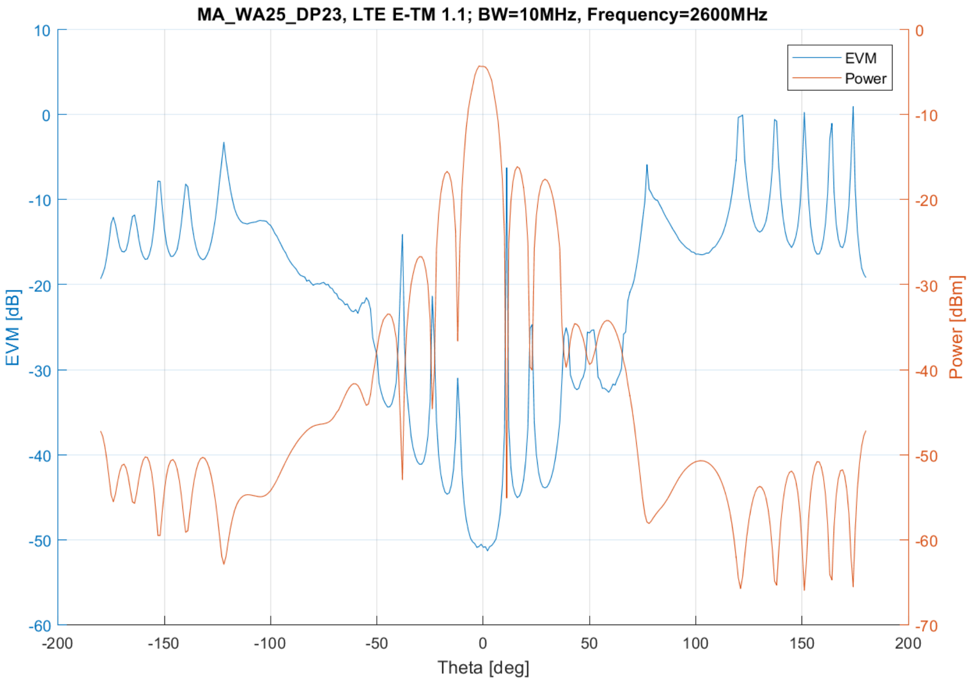
2. Active AUT TX
   - Array calibration (mag, phase)
   - EiRP, EVM, ACLR, SEM, pattern, …
   - Planar pattern of power density
   - Beam Tilt

3. Active AUT RX
   - Array calibration (mag, phase)
   - EIS, TIS, Throughput, BER, pattern, …





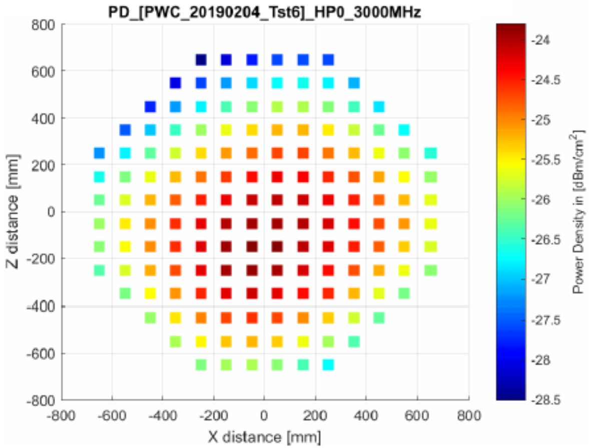
Measurements results



ROHDE&SCHWARZ

Unique capabilities

1. Bi-directional antenna converting arbitrary signal into plane wave
2. 4 x less space than CATR
3. Instantaneous OTA characterization of active and passive DUTs
4. Electronic plane-wave scanning *of DUT*



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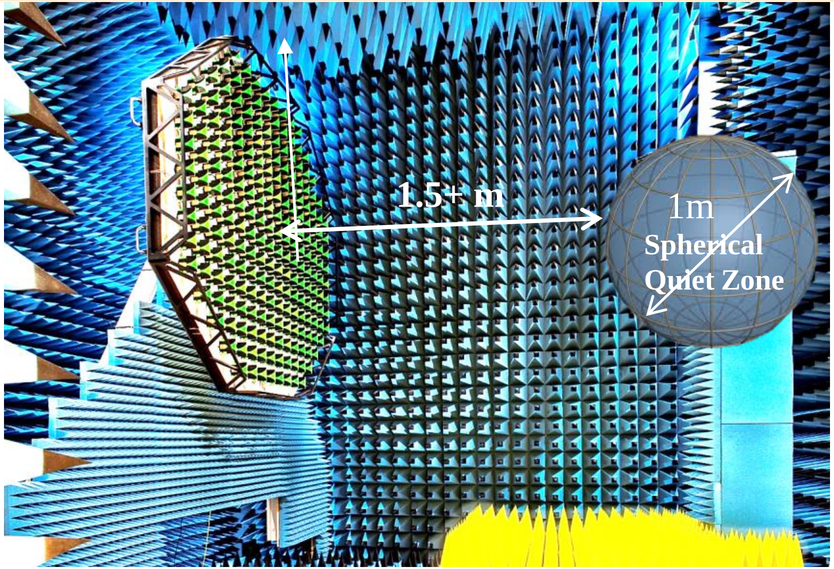
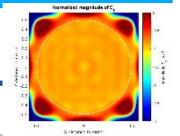
Plane Wave Converter Specifications

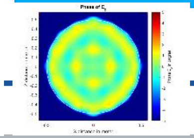
PWC200 Setup



QZ Mag



QZ Phase

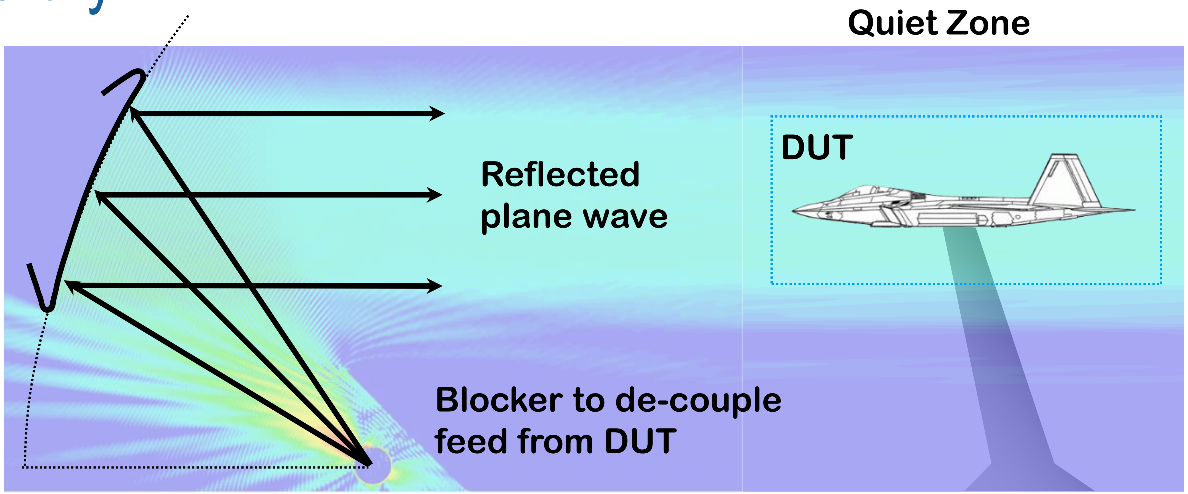


Parameters	Values
Signal Bandwidth	100-200 MHz (Modulated and CW)
Frequency Band	2.3 – 3.8 GHz (v1) & 2.3 – 6 GHz (v2)
Separation Distance	1.5 meters
Quiet Zone Size	1.0 meter diameter (0.75x0.75m DUT)
Speed (Far field EVM)	< 1 second
Measurement Capabilities	EVM, ACLR, SEM, EiRP, Gain
PWC Size	1.8 meter diameter (~2 times QZ size)
Range Length	1.5 meters (separation between PWC and DUT)

FR2 – Device OTA testing

3GPP requires Black Box Testing → CATR
Theory & History

Parabolic main reflector with blended rolled edges



Originally developed in 1969 to measure airplane radar cross section

Primary feed antenna at focus of main reflector

Low scattering mount

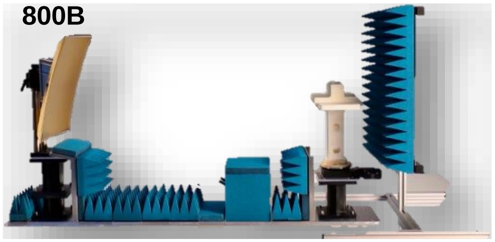
Minimum Frequency = Edge treatment

CATR Bandwidth

Maximum Frequency = Surface roughness

CATR: Compact Antenna Test Range

CATR Models



Benchtop: Flexibility	Rack: Simplicity	Chamber: Completeness
Quiet Zone Size: 20x20cm		Quiet Zone Size: 30x30cm
Positioner: 2D (Available in 2019 for 800R)		Positioner: 3D
No Shielding	SE ~ 50 dB	SE ~ 70+ dB
Footprint: 0.8 m2		Footprint: 1.3 m^2

ATS800R Rack-Mounted System

Adjustable rolled-edges reflector

Frequency range for measurements: 15 … 85 GHz

Enough space for prototype boards up to 40x40 cm
QZ size (20-50GHz): 20cm

Dimensions: 80x100x210cm

Basic absorbers: Walls, ceiling, and below DUT

Wide-band feed antenna

Space for instruments (14 HU)
Callbox, FSW, SMW, OSP, or ZVA

R&S CATR Performance

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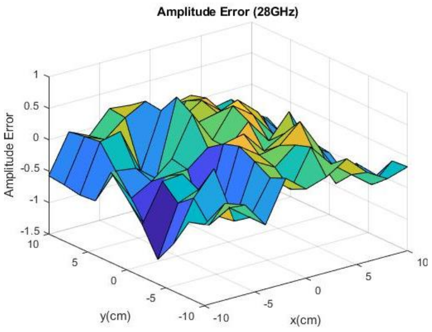
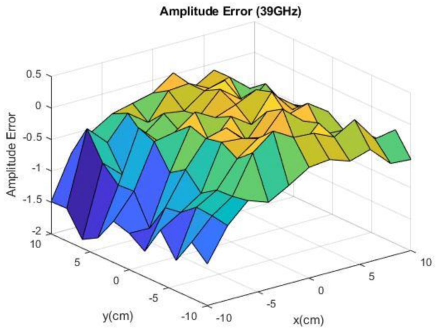
XY Scan of Reflector for ATS800B/800R: Amplitude & Phase

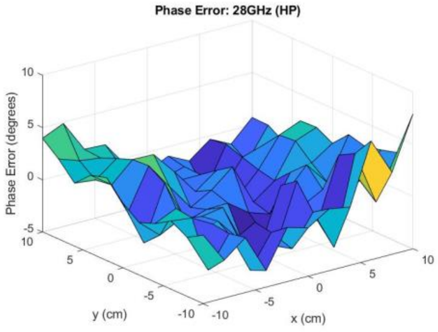
Amplitude Scan: 28GHz | **Amplitude Scan: 39GHz**

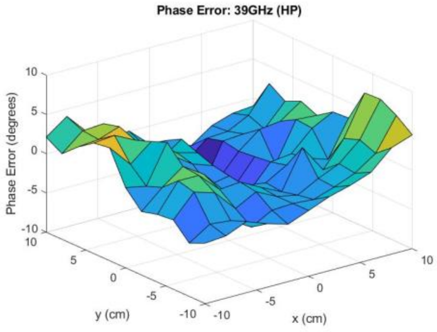




Amplitude Error	Peak2Peak	Mean Error	RMS Error
28 GHz (Square)	1.8 dB	0.3 dB	0.4 dB
28 GHz (Cylindrical)	**1.6 dB**	0.3 dB	0.3 dB
39 GHz (Square)	2.1 dB	0.4 dB	0.6 dB
39 GHz (Cylindrical)	**1.9 dB**	0.3 dB	0.4 dB

Phase Scan: 28GHz | **Phase Scan: 39GHz**

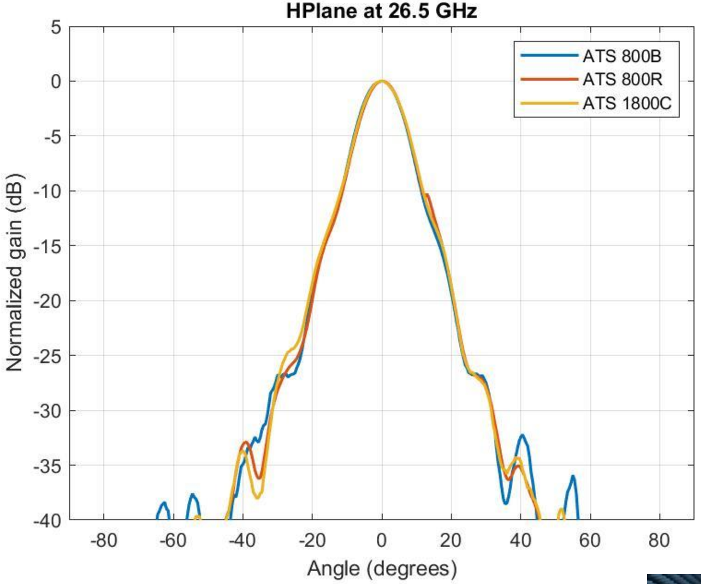


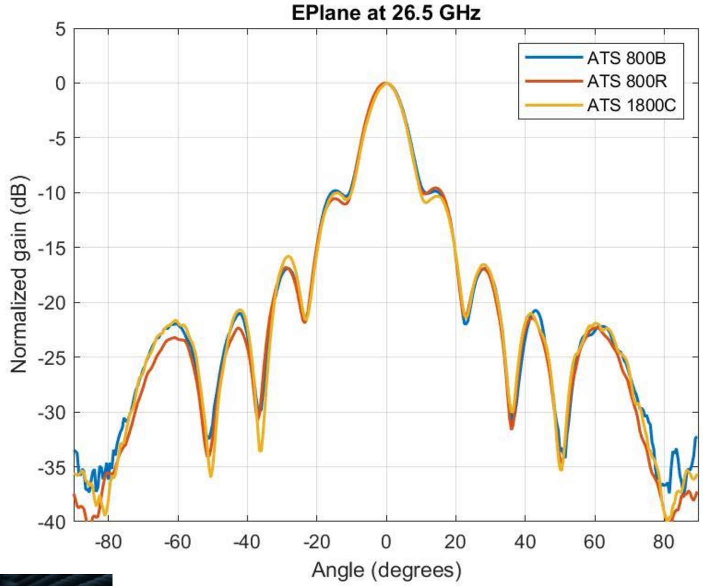


Phase Error	Peak2Peak	Mean Error	RMS Error
28 GHz (Square)	12.7 degrees	1.8 degrees	2.3 degrees
28 GHz (Cylindrical)	**10.1 degrees**	1.4 degrees	1.7 degrees
39 GHz (Square)	13.8 degrees	2.0 degrees	2.5 degrees
39 GHz (Cylindrical)	**11.2 degrees**	1.8 degrees	2.1 degrees

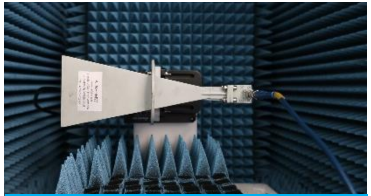
Measurement results from Accredited External OTA Lab

Normalized Gain Pattern Comparison: 26.5GHz





Note: 800R & 1800C SLL equivalent to Far-Field distance of *$4D^2/\lambda$* –>
Phase Variation < 11 degrees



DUT/Reference Antenna

"If you want to go fast, go alone.
If you want to go far, go together!"

African proverb